Marine Institute
Foras na Mara

The “Smalls” *Nephrops* Grounds (FU22) 2020 UWTV Survey Report and catch scenarios for 2021

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Version 1.0

Ireland's European Structural and Investment Funds Programmes 2014-2020
Co-funded by the Irish Government and the European Union

Department of Agriculture, Food and the Marine
An Roinn Talmhaíochta, Bia agus Mara

EUROPEAN MARITIME AND FISHERIES FUND

Abstract

This report provides the main results and findings of the fifteenth annual underwater television survey on the ‘Smalls grounds’ ICES assessment area; Functional Unit 22. The survey was multi-disciplinary in nature collecting UWTV and other ecosystem data. A total of 40 UWTV stations were surveyed successfully (high quality image data), carried out over an isometric grid at 4.5nmi or 8.3km intervals. The precision, with a CV of 8%, was well below the upper limit of 20% recommended by SGNEPS (ICES, 2012). The 2020 abundance estimate was 33% lower than in 2019 and at 750 million is below the MSY $B_{trigger}$ reference point (990 million). Using the 2020 estimate of abundance and updated stock data implies catch in 2021 that correspond to the F ranges in the EU multi annual plan for Western Waters are between 1238 and 1560 tonnes (assuming that discard rates and fishery selection patterns do not change from the average of 2017–2019). One species of sea pens was recorded as present at the stations surveyed: *Virgularia mirabilis*. Trawl marks were observed at 48% of the stations surveyed.

Key words: *Nephrops norvegicus,* stock assessment, geostatistics, underwater television (UWTV), benthos.

Suggested citation:
Aristegui, M., Blaszkowski, M., Doyle, J., Ryan, G., and McAuliffe, M. 2020. The “Smalls” *Nephrops* Grounds (FU22) 2020 UWTV Survey Report and catch scenarios for 2021. Marine Institute UWTV Survey report.

Introduction

The prawn (*Nephrops norvegicus*) are common in the Celtic Sea occurring in geographically distinct sandy/muddy areas where the sediment is suitable for them to construct their burrows (Figure 1). The *Nephrops* fishery in ICES sub-area 7 is extremely valuable with Irish landings in 2019 worth around €42 m at first sale. The Celtic Sea area (Functional Units 19-22, see Figure 1) supports a large multi-national targeted *Nephrops* fishery, mainly using otter trawls and yielding landings in the region of ~5,000 t annually over the last decade (ICES, 2020). The 2019 reported landings from the Smalls (~1639 t) were estimated to be worth in the region of €8.8 million at first sale. The Smalls ground is particularly important to the Irish demersal fleet accounting for around 13% of the fishing effort by all demersal vessels >15m between 2006 and 2009 (Gerritsen, *et al.,* 2012). The Irish demersal fleet now account for ~ 90% of the FU22 *Nephrops* landings (ICES, 2020). Good scientific information on stock status and exploitation rates are required to inform sustainable management of this resource.

Nephrops spend a great deal of time in their burrows and their emergence behaviour is influenced by several factors: time of year, light intensity, tidal strength, etc. Underwater television surveys and assessment methodologies have been developed to provide a fishery independent estimate of stock size, exploitation status and catch advice (ICES, 2009 & 2012). This is the fifteenth in a time series of UWTV surveys in the Celtic Sea FU22 “Smalls” ground carried out by the Marine Institute, Ireland.

The survey was multi-disciplinary in nature and and also covered UWTV stations in FU16, FU19 and FU2021 the results of which are presented elsewhere (Aristegui *et. al*., 2020a-c,).

The specific objectives of the 2020 survey are listed below:

1. To complete a survey of 40 randomised fixed isometric grid UWTV stations, with 4.5 nautical mile (nmi) spacing, on the “Smalls” *Nephrops* ground (FU22).
2. To obtain 2020 quality assured estimates of *Nephrops* burrow distribution and abundance on the "Smalls” *Nephrops* ground (FU22) and compare them with those collected in previous surveys.
3. To collect ancillary information from the UWTV footage collected at each station such as the occurrence of sea-pens, other macro benthos and fish species and trawl marks on the sea bed.
4. To sample *Nephrops* and macro benthos using a 3 metre beam trawl deployed at 10 stations once UWTV operations successfully completed.
5. To collect sediment samples for a *Nephrops* Microplastic research project.

This report details the final UWTV results of the 2020 survey and documents other data collected during the survey. Operational survey details are available in form of a survey narrative available from the scientist in charge (MA). The 2020 abundance estimate is used to generate catch scenarios for 2021 in line with procedures outlined in the stock annex for FU22 (ICES, 2017).

Material and methods

To maintain a coefficient of variance (CV) < 20%, to achieve good spatial coverage over the ground and to generate burrow surface that reflects the underlying abundance of *Nephrops*, a survey grid of 4.5 nm spacing has been used since 2012. The 2020 randomised isometric grid, which resulted in 40 planned stations, was generated using using the “spsampl” function in the “sp” package (Pebesma & Bivand, 2005) in “R” (R Core Team, 2017). The boundary used to delineate the edge of the ground was based on information from VMS (Gerritsen & Lordan, 2011), habitat maps, and previous UWTV observations. The same boundary has been used through the time series.

The 2020 Celtic Sea survey took place on RV Celtic Voyager between the 15th July and the 21st July. The survey normally takes place in either July or August each year.

In 2020 image data were collected by a custom built camera system recording High Definition still image data at 12 frames per second with a camera angle of 75 (°). The digital images were stored on a server and were reviewed ashore through an in-house developed Image annotation R Shiny app (Aristegui, 2020). This app allows each reviewer to annotate burrows for each randomly assigned station in an efficient manner. The survey process is now paperless.

The operational protocols used were those reviewed by WKNEPHTV 2007 (ICES, 2007) and employed on other UWTV surveys in Irish waters. These protocols can be summarised as follows: At each station the UWTV sledge was deployed. Once stable on the seabed a 10 minute tow was recorded. Time referenced high definition image data was collected with a field of view or ‘FOV’ of 1.01 metre. Vessel position (DGPS) and position of sledge (using a USBL transponder) were recorded every 3 seconds. The navigational data were quality controlled using an “R” script developed by the Marine Institute (ICES, 2009) an example is shown in Figure 3. In 2020 the USBL navigational data were used to calculate distance over ground for 100% of stations.

In line with recommendations of the Workshop on *Nephrops* Burrow Counting (WKNEPS), all scientists were trained/re-familiarised using 2019 image data for training material and reference set (ICES, 2018). All counts were conducted by four trained scientists independent of each other after the survey. The numbers of *Nephrops* burrows systems (multiple burrows in close proximity which appear to be part of a single system) were counted as one. *Nephrops* activity in and out of burrows were counted and recorded for each station. Following the recommendation of SGNEPS the time for verified recounts was 7 minutes (ICES, 2009).

Presence / absence notes were also recorded on the occurrence of trawl marks, fish species and other species. Presence / absence of sea-pen species were also recorded to fulfil an OSPAR Special Request (ICES, 2011).

Finally, if there was any time during the one-minute block where counting was not possible, due to sediment clouds or other reasons, this was also estimated so that the time could be removed from the distance over ground calculations.

In 2020 the survey count data were screened to check for any unusual discrepancies using Lin’s Concordance Correlation Coefficient (CCC) with a threshold of 0.6. Lin’s CCC (Lin, 1989) measures the ability of counters to exactly reproduce each other’s counts on a scale of 1 to -1 where 1 is perfect concordance (i.e. a pairwise plot will have all points lying along the 1:1

line). A value of -1 would be generated by all points lying on the -1:1 line and a value of 0 indicates no correspondence at all. Lin's CCC quality control plots of survey count data for stations 120 to 122 is shown in Figure 4. When the count data fell below the threshold of 0.6 a third review was carried out. The paired count data that passed the Lin's CCC threshold was used in the analysis. When the paired counts did not pass the threshold an average of the three reviewers was deemed appropriate to use in the analysis.

Mean density was calculated by dividing the total number of burrow systems by the survey area observed. The USBL data were used to calculate distance over ground of the sledge. The field of view of the camera at the bottom of the screen was estimated by extrapolation at 1.01m assuming that the sledge was flat on the seabed (i.e. no sinking). Occasionally the lasers were not visible at the bottom of the screen due to sinking in very soft mud. The impact of this is a minor under estimate of densities at stations where this occurred.

From 2006 to 2014 calculation of spatial co-variance, spatial structuring, geo-statistical analysis of the mean and variance was carried out using SURFER Version 10.7.972. From 2015 the geostatistical analysis was carried out using the "RGeostats" package (Renard D., *et al*, 2015) and is available as a separate "R markdown" document. The same basic steps were carried out as in previous years; construction of experimental variogram, a model variogram produced with an exponential model, create krigged grid file using all data points as neighbours, same boundary used to estimate the domain area, mean density, total burrow abundance and calculate survey precision.

Due to time constraints beam trawling was not carried out on the "Smalls" ground this year. Sediment samples at three stations were collected for a research project to determine micro-plastics loading in *Nephrops norvegicus* and sediments.

Results

In 2020 40 stations were completed successfully on the Smalls. A summary of the results is presented in Table 1. The density and estimated abundance decreased by around 33% in 2020. The average density and the abundance were the lowest in the time series. Figure 5 shows bubble plots of the variability between minutes and operators. These show that the burrow estimates are very consistent between minutes and counters. A combined violin and box plot of the observed burrow densities is presented in Figure 6. This shows that median and mean burrow densities are similar in most years. The inter-quartile range is between 0.2 and 0.7 in most years. However, in 2020 as in 2018 and 2016, this inter-quartile range is in the region of 0.1 to 0.4. In 2020 the mean adjusted[1] burrow density was 0.27 burrows/m^2.

The krigged and point density data for 2006-2020 are shown in Figure 7. The krigged contours correspond well to the observed data. Highest densities are in the centre of the ground in all years. In general, densities are higher towards the south, west and central area of the ground.

[1] Note the "adjusted" density estimates in this report are adjusted by dividing by 1.3 (Table 2) to take account of edge effect over estimation of area viewed during UWTV transects (see Campbell et al 2009).

The annual survey statistics from this geo-statistical analysis are given in Table 1 and Figure 8. The 2020 estimate of 750 million burrows is below the geometric mean of the series (geomean [2006-2020]: 1184 million burrows) and is below the MSY $B_{trigger}$ reference point of 990 million. The estimation of variance of the 2020 survey as calculated by RGeostats is low (with a CV or RSE of 8%), which is well below the SGNEPS recommendation for a CV <20% (ICES, 2012).

Figure 9 shows the standardised length frequency distributions of *Nephrops* caught using a beam trawl. Fishing operations were not carried out during 2010, 2013, 2014, 2015 and 2019 due to time constraints. For plotting purposes, the individuals <10mm caught were split evenly between males and females as it is not possible to accurately assign sex to individuals of this size. A strong cohort was apparent in the 2006 catches of around 17mm and can be tracked in catches in subsequent years. There was a shift to larger sizes in 2011 and 2012, with a shift back again to smaller sizes in 2016 to 2018.

Sea-pen presence/absence distribution across the Smalls *Nephrops* grounds is mapped in Figure 10. One sea-pens were identified from the image data in 2020, that is, *Virgularia mirabilis*. Trawl marks were noted at 48% of the stations surveyed.

The UWTV abundance data together with data from the fishery; landings, discards and removals in number, were used to calculate the harvest rate for 2019 of 8.5%. The mean weight in the landings and discards and the proportions of removal retained are also shown (Table 2).

The basis to 2021 catch scenarios are given in Table 3. The catch and landings scenarios at various different fishing mortalities were calculated in line with the stock annex of the Report of the Working Group on Celtic Seas Ecoregion (ICES, 2020) using the 2020 survey abundance (Table 3). The latest estimate of stock abundance (value from July 2020 survey, 750 million) is below the MSY $B_{trigger}$ value (990 million). When the EU multiannual plan (MAP) for Western Waters and adjacent waters is applied (EU, 2019), catches in 2021 that correspond to the F ranges in the MAP are between 1238 and 1560 t (Table 4). This assumes that discard rates and fishery selection patterns do not change from the average of 2017–2019.

Discussion

Since 2006 a dedicated annual UWTV survey has taken place which gives abundance estimates for this ground with high precision. The burrow abundance and mean density estimates have decreased in 2020 to the lowest level observed in the series. Fluctuations in density has also been observed in the adjacent FU20-21 and FU19 this year (Aristegui *et. al,* 2020 and Doyle *et. al,* 2020). Sudden declines followed by large increases in abundance have also been observed in other *Nephrops* stocks in the past (e.g. FU12 and FU13 in 2012-2013).

Nephrops in this area have been covered under the landings obligation since 2016 with several exemptions. Discard rates in weight for this FU have been around 12% in recent years. The provision of catch advice and scenarios for 2020 based on EU multiannual plan (MAP) for Western Waters assumes that discard rates and fishery selection patterns do not change from the average of 2017-2019.

The introduction of the landings obligation to *Nephrops* fisheries in 2016 should result in changes in selectivity. This is not taken into account in any of the catch advice because it is not possible to predict exactly what might happen. The main message is that any improvements in selectivity in the fishery and reductions in discards will result in increased mean weight in the catches. This will in turn reduce overall mortality on the stocks and allow for catch increases in the future.

An important objective of this UWTV survey was to collect various ancillary information. The occurrence of trawl marks on the footage is notable for two reasons. Firstly, it makes identification of *Nephrops* burrows more difficult as the trawl marks remove some signature features making accurate burrow identification more difficult. Secondly, only occupied *Nephrops* burrows will persist in heavily trawled grounds and it is assumed that each burrow is occupied by one individual *Nephrops* (ICES, 2008).

Monitoring the occurrence and frequency of sea-pens observed on this ground is important in the context of OSPAR's designations of sea-pen and burrowing megafauna communities as threatened. The sea-pen species *Virgularia mirabilis* which was seen in 2020 have been observed on previous surveys of FU22. Monitoring *Nephrops* stock and the benthic habitat is also important in the context of the MFSD indicators (e.g. sea floor integrity*).*

The main objectives of the survey were successfully met for the fifteenth successive year. The UWTV coverage and footage quality was excellent throughout the survey. This was mainly due to good survey planning to coincide with slack tides. The multi-disciplinary nature of the survey means that the information collected is highly relevant for a number of research and advisory applications.

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Acknowledgments

We would like to express our sincere thanks and gratitude to Colin McBrearty (Master) and crew of the RV. Celtic Voyager. Thanks to the onboard P&O technical staff Lukasz Pawlikowski who maintained the UWTV system throughout the survey. Thanks to Aodhán Fitzgerald, Rosemarie Butler (RVOPs) and Dave Tully (FEAS) at the Marine Institute for organising survey logistics, and also Gordon Furey and Damian Crean (P&O Maritime) for shore side support.

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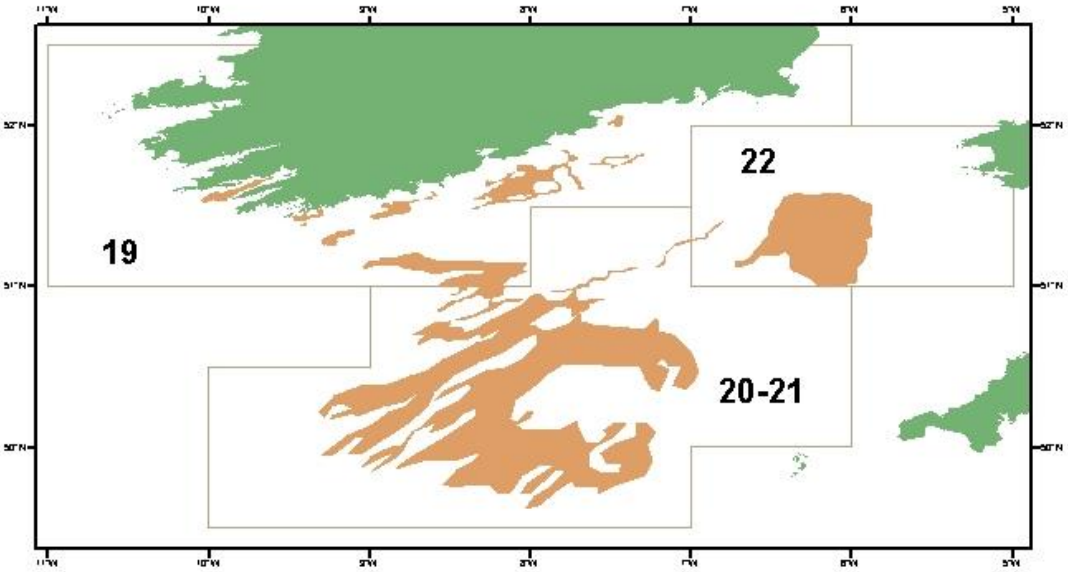

Figure 1: FU22 Smalls grounds: *Nephrops* Functional Units (FUs) and *Nephrops* grounds (area polygons) in the greater Celtic Sea.

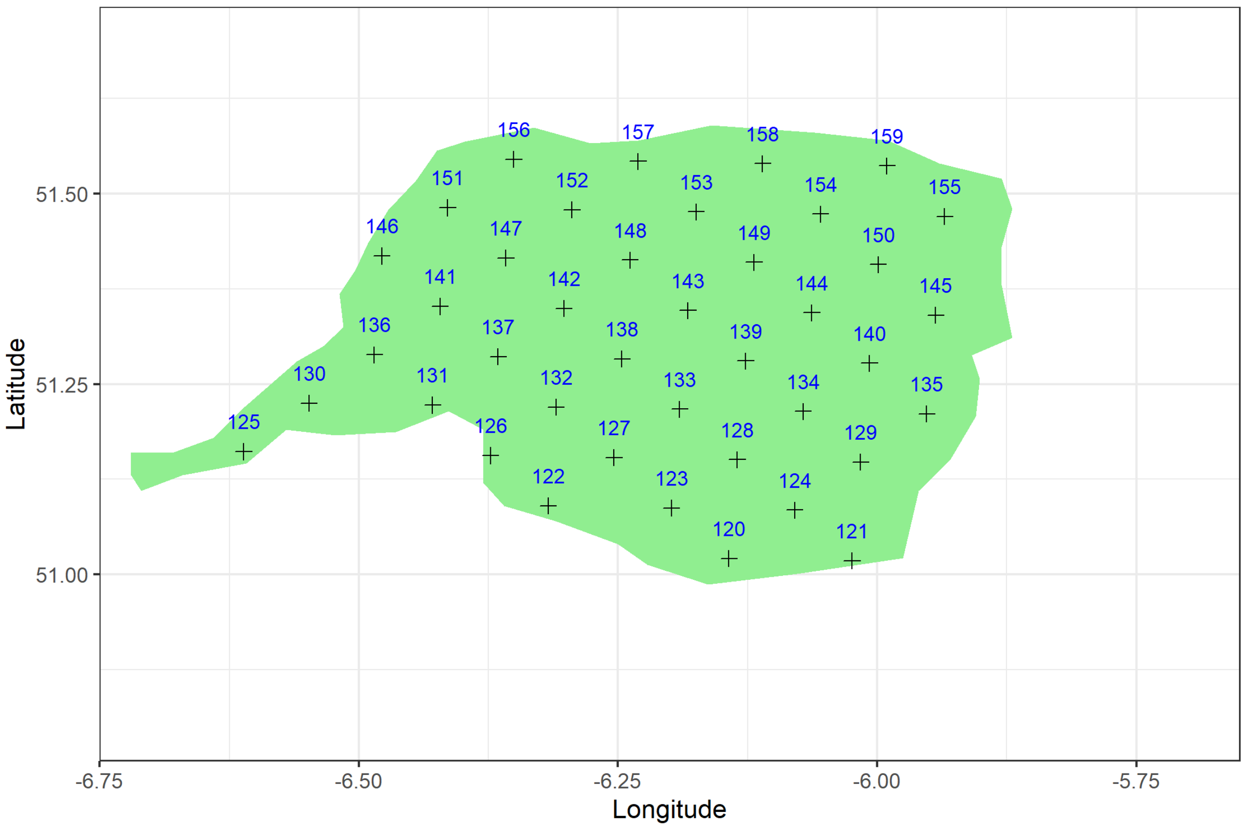

Figure 2: FU22 Smalls grounds: TV stations completed on the 2020 survey.

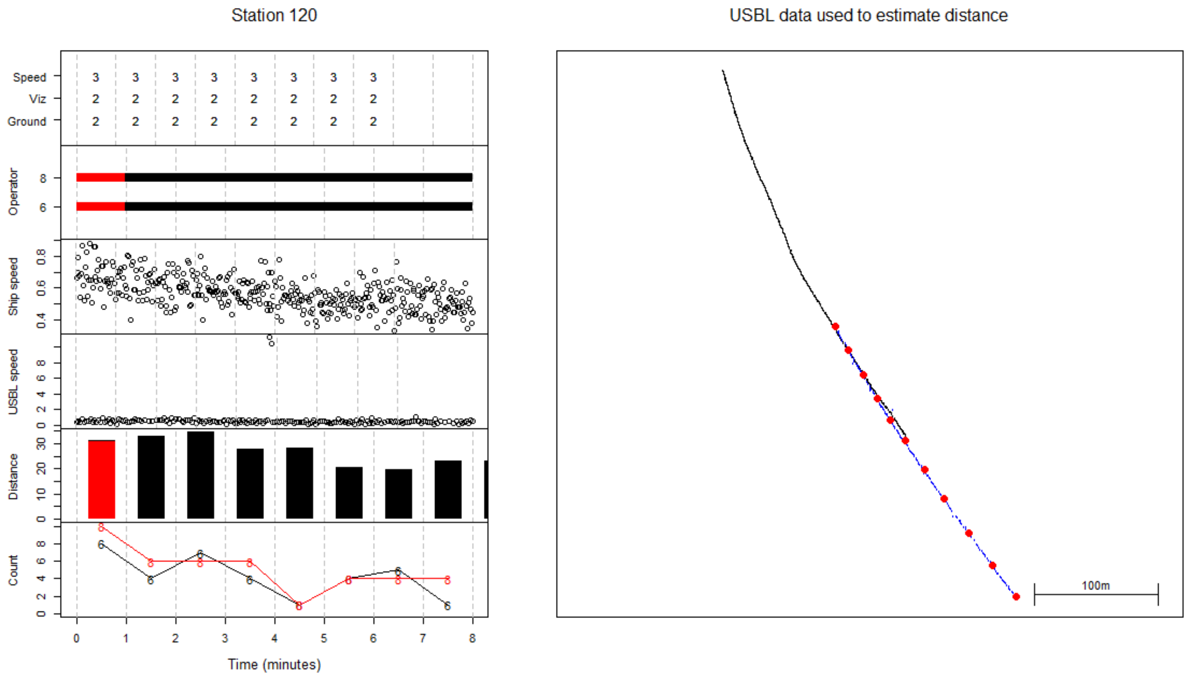

Figure 3 : FU22 Smalls grounds: R - tool quality control plot for station 120 of the 2020 survey.

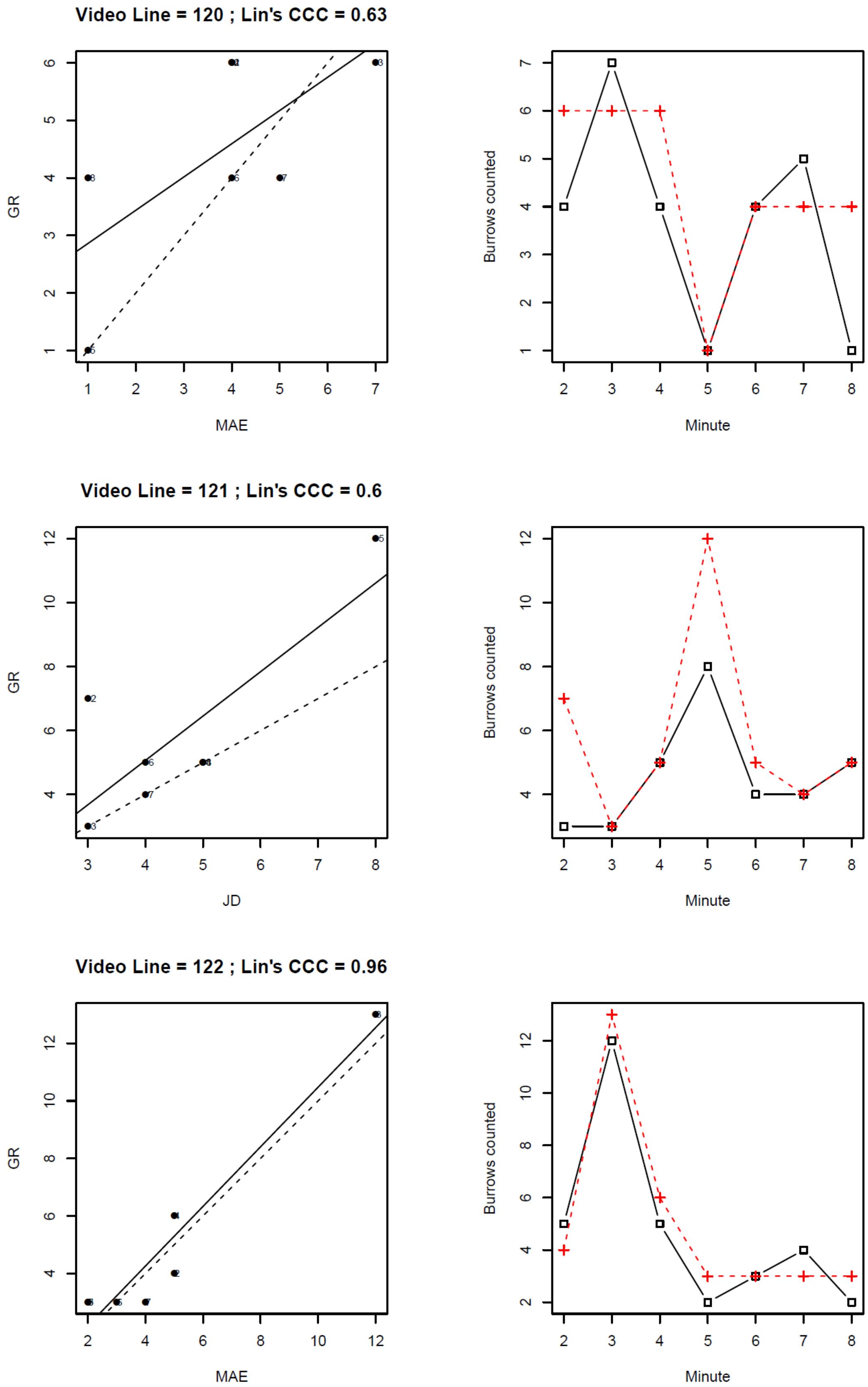

Figure 4 : FU22 Smalls grounds: Lin's CCC quality control plots of count data for stations 120 to 122 of the 2020 survey.

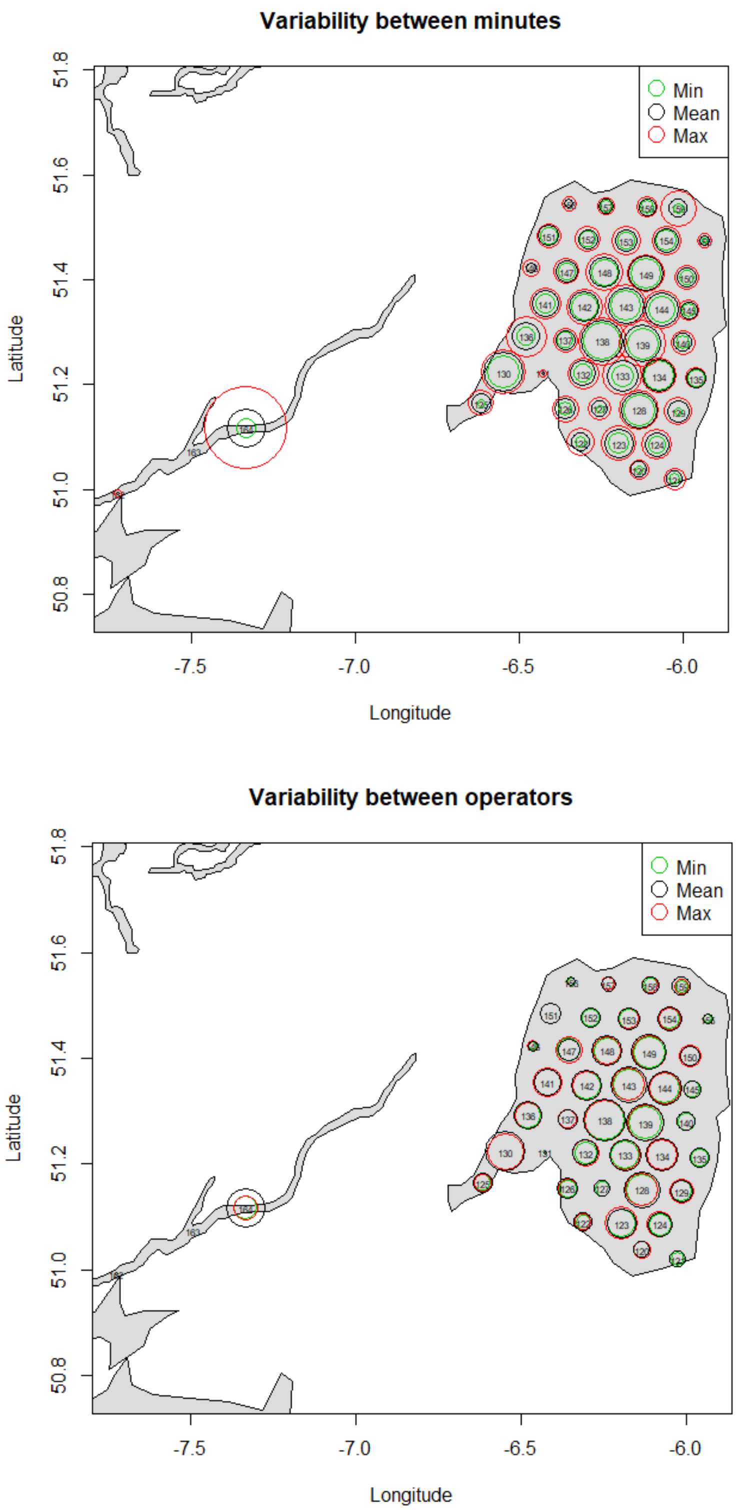

Figure 5 : FU22 Smalls grounds: Plots of the variability in density between minutes (top panel) and between operators (counters) (bottom panel) for each station in 2020

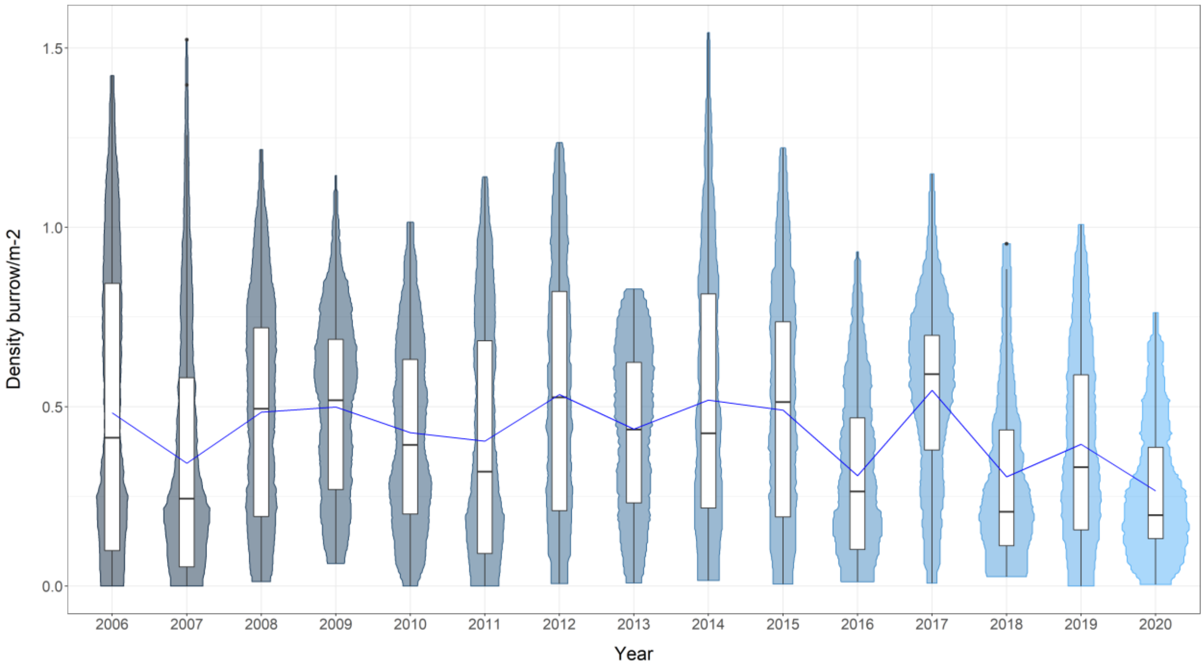

Figure 6: FU22 Smalls grounds: Violin and box plot of adjusted burrow density distributions by year from 2006 -2020. The blue line indicates the mean density over time. The horizontal black lines represent medians, white boxes the inter quartile ranges, the black vertical lines the range and the black dots are outliers.

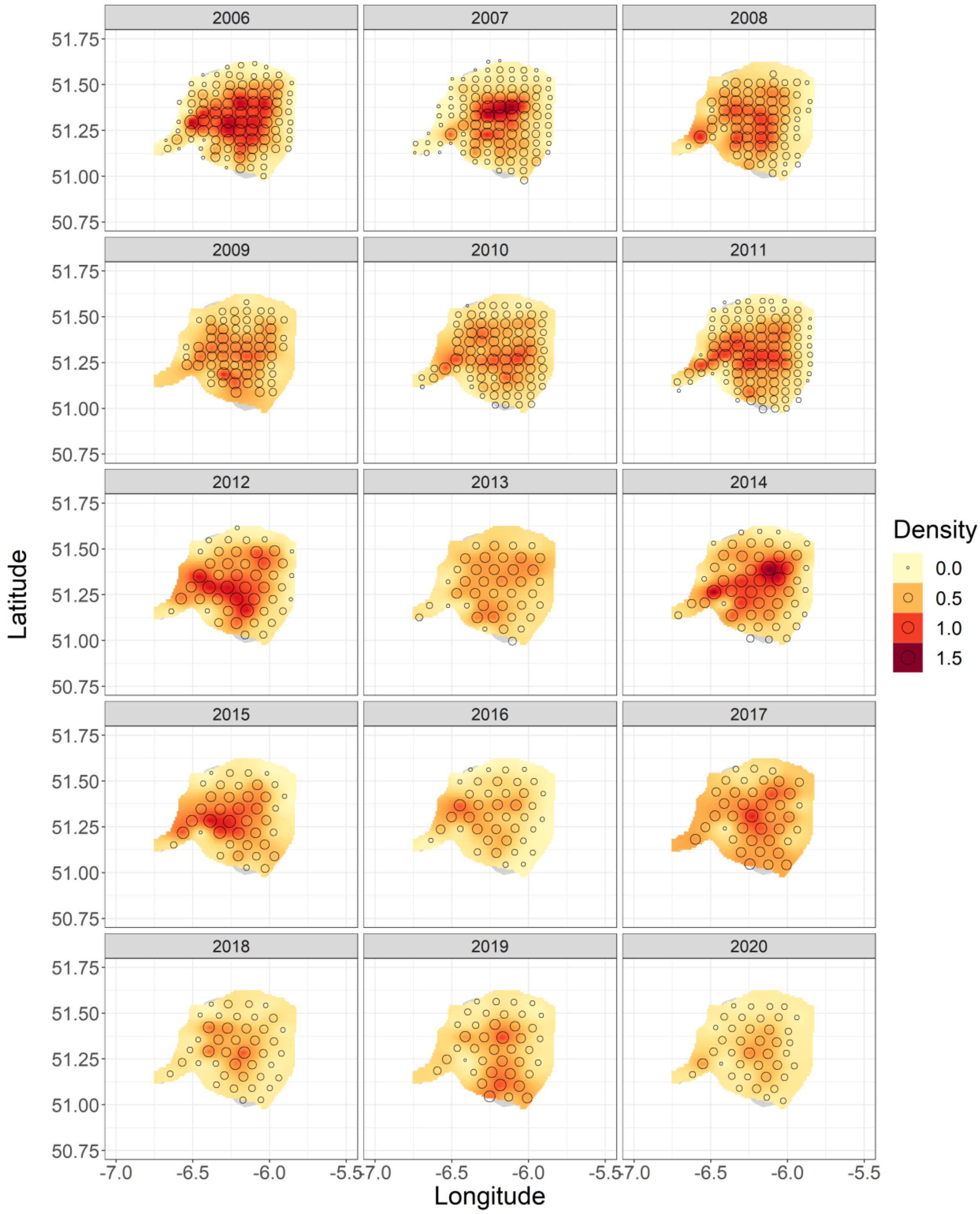

Figure 7: FU22 Smalls grounds: Contour plots of the krigged density estimates by year from 2006 (top left) - 2020 (bottom left).

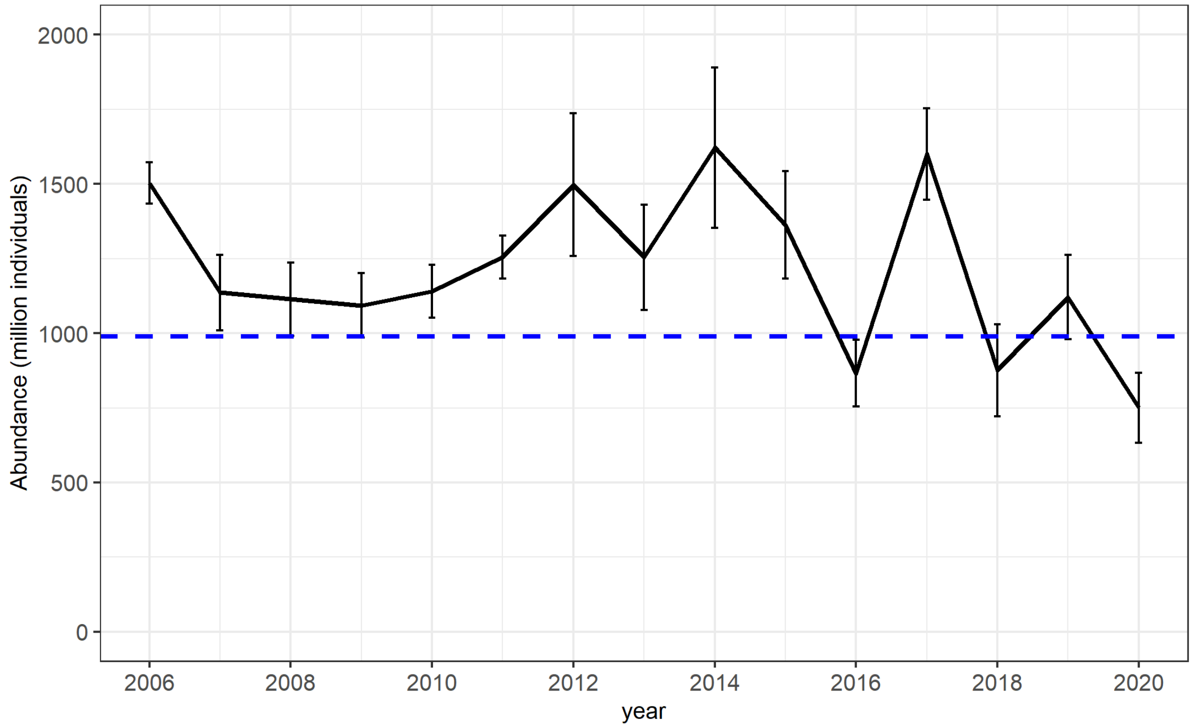

Figure 8: FU22 Smalls grounds: Time series of geo-statistical adjusted abundance estimates (in millions of burrows). The error bars indicate the 95% confidence intervals and $B_{trigger}$ is dashed blue line.

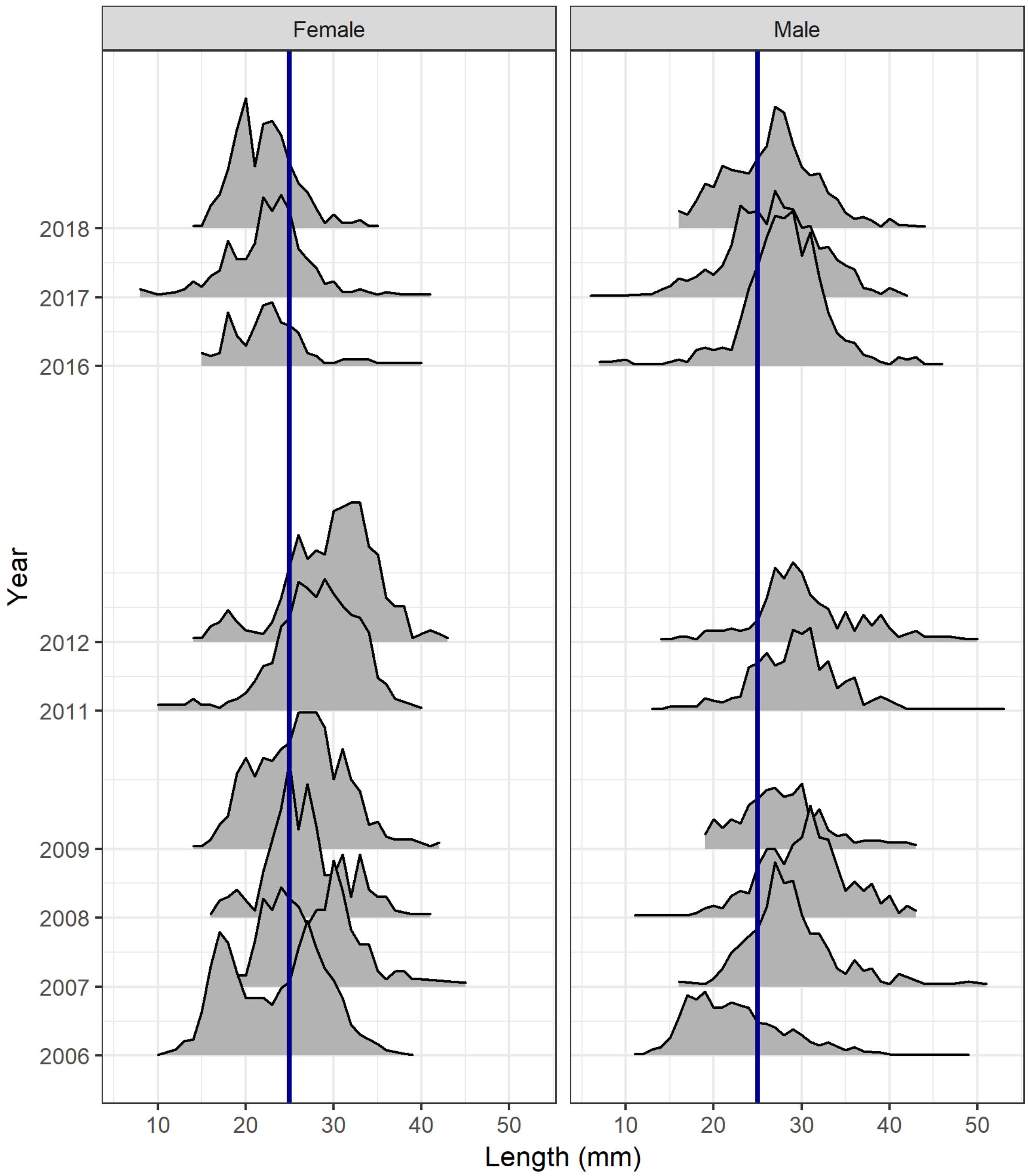

Figure 9: FU22 Smalls grounds: Standardised length frequency distributions for male and female *Nephrops* caught using beam trawl during 2006 to 2018 UWTV surveys (except years 2010, 2013 – 2015, 2019 - 2020). Blue line indicates minimum conservation reference size 25 mm carapace length.

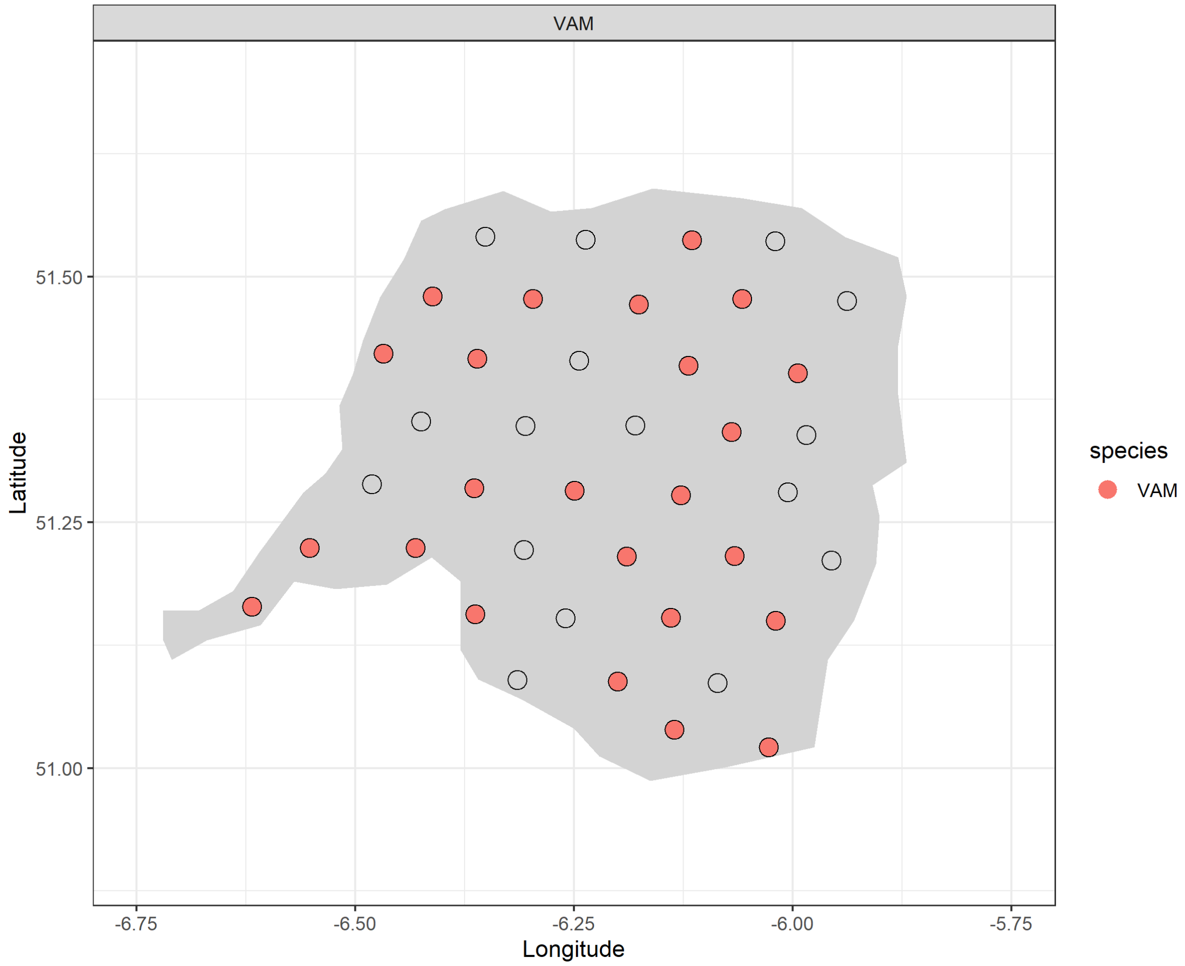

Figure 10: FU22 Smalls grounds: 2020 stations where *Virgularia mirabilis* (VAM) were identified. Closed circles indicated presence and open circles denotes TV stations with no sea-pen observations.

Table 1: FU22 Smalls grounds: Overview of geostatistical results from 2006-2020.

Year	Number of stations	Mean Density adjusted (burrow/m²)	Domain Area (km²)	Geostatistical Abundance adjusted (millions of burrows)	CV on Burrow estimate (%)
2006	100	0.49	2962	1503	2
2007	107	0.37	2955	1136	6
2008	76	0.36	2698	1114	6
2009	67	0.36	2824	1093	5
2010	90	0.37	2861	1141	4
2011	107	0.41	2881	1256	3
*2012	47	0.49	2934	1498	8
*2013	41	0.41	2975	1254	7
*2014	52	0.53	2970	1622	8
*2015	40**	0.49	3064	1363	7
*2016	41	0.31	3063	866	7
*2017	40	0.55	3063	1600	5
*2018	42	0.31	3063	876	9
*2019	41	0.40	3063	1121	6
*2020	40	0.27	3063	750	8

*reduced randomised isometric grid

** In 2015 seven of the stations were filled in with an estimate based on the mean density of historical stations within 2 nmi of the planned station.

Table 2: FU22 Smalls grounds: Inputs to catch scenarios table.

Year	UWTV abundance estimate	95% Confidence Interval	Landings in number	Total discards in number*	Removals in number	Harvest rate (by number)	Landings	Total discards*	Discard rate (by number)	Dead discard rate (by number)	Mean weight in landings	Mean weight in discards
	millions					%	tonnes		%		grammes	
2003			95	68	146		2065	720	41.5	34.7	21.7	10.7
2004			71	13	80		1828	202	15.6	12.2	25.9	15.4
2005			119	129	216		2533	1648	51.9	44.7	21.2	12.8
2006	1503	70	100	45	134	8.9	1761	454	31.1	25.3	17.6	10.1
2007	1136	126	165	181	301	26.5	2950	1906	52.3	45.1	17.9	10.5
2008	1114	123	144	26	163	14.6	3090	289	15.3	12.0	21.5	11.1
2009	1093	108	92	33	117	10.7	2185	371	26.4	21.2	23.7	11.3
2010	1141	88	122	45	155	13.6	2714	636	26.8	21.5	22.3	14.3
2011	1256	72	60	13	70	5.6	1636	196	18.0	14.1	27.3	14.9
2012	1498	239	120	31	144	9.6	2618	347	20.7	16.3	21.8	11.1
2013	1254	177	94	40	124	9.9	2257	497	30.0	24.3	24.1	12.4
2014	1622	268	100	33	125	7.7	2526	460	25.0	20.0	25.2	13.8
2015	1363	180	114	44	147	10.8	2350	450	28.0	22.6	20.6	10.1
2016	866	112	160	54	200	23.1	3329	519	25.1	20.0	20.8	9.7
2017	1600	153	164	39	194	12.1	3560	424	19.2	15.2	21.7	10.8
2018	876	154	98	31	121	13.8	1975	350	23.7	19.0	20.2	11.2
2019	1121	141	81	19	95	8.5	2083	262	19.1	15.1	25.8	13.7
2020	750	118										

Table 3: The basis for the catch scenarios.

Variable	Value	Notes
Stock abundance (2021)	750	Number of individuals (million); UWTV survey 2020
Mean weight in projected landings	22.5	Average 2017–2019 in grammes
Mean weight in projected discards	11.8	Average 2017–2019 in grammes
Projected discards	20.7	Proportion by number; average 2017–2019
Discards survival*	25	Proportion by number
Projected dead discards	16.4	Proportion by number; average 2017–2019

*Only applied in scenarios where discarding is allowed

Table 4: FU22 Smalls grounds: Annual catch advice and scenarios; Discarding assumed to continue at recent average.

Basis	Total catch	Dead removals	Projected landings	Projected dead discards	Projected surviving discards	Harvest rate * %	% advice change **
	PL + PDD + PSD	PL + PDD	PL	PDD	PSD	for PL + PDD	
ICES advice basis							
MSY approach; F = EU MAP^: F_{MSY} × Stock Abundance 2020 / MSY $B_{trigger}$	1560	1512	1371	141	47	9.7	-45
MAP $F_{MSY\ lower}$ × Stock Abundance 2020 / MSY $B_{trigger}$	1238	1201	1088	112	37	7.7	-45
MAP $F_{MSY\ upper}$ × Stock Abundance 2020 / MSY $B_{trigger}$	1560	1512	1371	141	47	9.7	-45
Other options							
F = MAP F_{MSY}	2058	1996	1809	187	62	12.8	-27
F = MAP $F_{MSY\ lower}$	1640	1591	1442	149	50	10.2	-42
F = MAP $F_{MSY\ upper}$***	2058	1996	1809	187	62	12.8	-27
F_{2019}	1366	1325	1201	124	41	8.5	-52

^ EU multiannual plan (MAP) for Western waters (EU, 2019).
* By number.
** Advice value for 2021 relative to the corresponding 2020 values (MAP advice value of 2820, 2247 and 2820 tonnes, respectively; other values are relative to F_{MSY}).
*** $F_{MSY\ upper}$ = F_{MSY} for this stock.